A Rain Gauge System using a Capacitance Sensor

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***Abstract*—This paper proposes a rain gauge system using a coaxial capacitance sensor. The proposed system consists of a high-pass filter, a coaxial capacitance sensor, SMS module, a microcontroller and a smartphone. The sensor capacitance is proportional to the rainfall levels. It is converted into voltage signal. The corresponding voltage signal is sent to the microcontroller for converting the signal levels to the rainfall levels in millimetres. The microcontroller sends the rainfall levels to the SMS module that then sends the rainfall level data to show on the display screen of the smartphone. The experimental results showed that the proposed prototype can provide the correct data compared to the traditional system.**

Keyword-Capacitance sensor, Rain Gauge, High-pass Filter

I. INTRODUCTION

Severe flooding affected some areas in Thailand during the 2011 monsoon season. In late June 2011, Thailand dominated by the remnant of tropical depression "Haima" led to extreme high rainfall in several areas. At the end of July 2011, heavy rain continued in many areas with the tropical depression "Nok-Ten." This brought heavy rain to several areas resulted in widespread flooding through the provinces of northern, north-eastern, and central Thailand along the Mekong, Chi, Mun, and Chao Phraya river basins [1]. Thai government reported that as many as 1.5 million homes and other structures were impacted throughout the duration of the severe floods. More than 884 people were killed. The World Bank reported that total economic losses to households were estimated at 45.7 Billion Dollars [2]. Fig. 1 illustrates the water flood damage in a community in Thailand.

Fig. 1: A photograph of the water flood in a community in Thailand in 2011 [2]

Many rural villages have no access to flood warning telemetry system. Therefore, the flood warning telemetry system is required for them.

Recently, electronics systems involve with measurements of basic physical quantities [3-4]. There are many techniques for liquid level measurement in research community [5-7]. Donlagic applied an acoustical gas resonator to send and receive signals for liquid level analysis [5]. Wang applied a digital camera to take floating switch's pictures, and analyzed the pictures for liquid level estimation [6]. Sohn monitored the liquid level using the Fiber Bragg grating embedded in the cantilever [7].

The requirements for the rural community's research are ease, low cost, and efficacy. The aforementioned techniques are very complicated. They are not appropriate for rainfall measurement techniques and the flood warning telemetry system for the rural communities. For measurement technologies, relative permittivity changes or capacitive changes are used as a factor for monitoring the environments and for measuring the material properties [3].

In this paper, a high-pass filter circuit with a coaxial capacitance sensor and a resistor is proposed as a novel rainfall telemetry system for rural areas.

II. DESIGN OF THE PROPOSED RAIN GAUGE SYSTEM

The proposed technique aims to monitor the corresponding output voltages because of the sensor's capacitance changes when the coaxial capacitance sensor is immersed in the water. The coaxial capacitance sensor is made of Copper. The sensor is designed with the length (L=1000 mm), inner radius (R1=5 mm), and outer radius (R2=12.5 mm). The designed sensor is shown in Fig. 2.

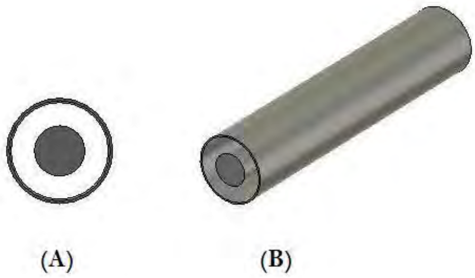

Fig. 2: (A) Front view of the sensor (B) Isometric view of the sensor

When the sensor is immersed in the water at the water level (H), the total capacitance (C) can be calculated from 2 parts (C1 and C2). C1 is the capacitance value of the sensor's part that is immersed in the water while C2 is the capacitance value of the sensor's part that is not immersed in the water. The total capacitance of the sensor is calculated as follow equations.

$$C = C1 + C2 \tag{1}$$

$$C = \frac{2\pi\varepsilon_r\varepsilon_0 H}{\ln\frac{R2}{R1}} + \frac{2\pi\varepsilon_0 (L-H)}{\ln\frac{R2}{R1}} \tag{2}$$

$$C = \frac{2\pi\varepsilon_0((\varepsilon_r - 1)H + L)}{\ln\frac{R2}{R1}} \tag{3}$$

when ε_0 is the vacuum permittivity (8.854×10^{-12} F/m) and ε_r is the relative permittivity of the water (78.3).

From the above equations, the equivalent circuit of the coaxial capacitance sensor immersed in the water can be illustrated in Fig. 3. Also the equations have shown that the total capacitance is proportional to the water level while the total capacitance is inversely proportional to the natural logarithm of the ratio of R2 and R1.

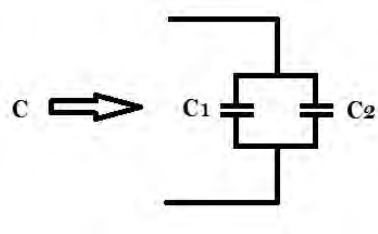

Fig. 3: The equivalent circuit of the coaxial capacitance sensor immersed in the water

The high-pass filter circuit is applied for the rainfall level measurement circuit. It can convert the capacitance changes because of the water level changes into the corresponding output voltages and send the output voltage to the microcontroller for rainfall analysis. The high-pass filter circuit for the system consists of an AC voltage source (Vi) with 5 V_{PEAK} and 16 kHz, a coaxial capacitance sensor (C), and a resistor(R=2,000 Ohm) in Fig. 4.

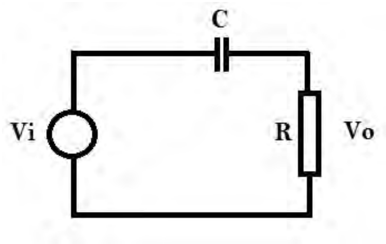

Fig. 4: The high-pass filter circuit for the rainfall telemetry system

From the circuit in Fig. 4, the corresponding output voltage (Vo) can be calculated as follows.

$$V_0 = \frac{R}{R - j\dfrac{1}{2\pi fC}} V_i \tag{6}$$

From the equation (6), it can be seen that the corresponding output voltage is proportional to the sensor capacitance when the frequency, the resistor, and the amplitude of the AC voltage source are fixed. This relationship can be used for the rainfall analysis.

III. RESULTS AND DISCUSSIONS

The coaxial capacitance sensor is tested in this section. The sensor is immersed in the water while the output voltage (peak voltage) is measured. The output voltage (peak voltage) is linearly proportional to the water level as shown in Fig. 5. This relationship can be used for monitoring the water level in the proposed rain gauge system.

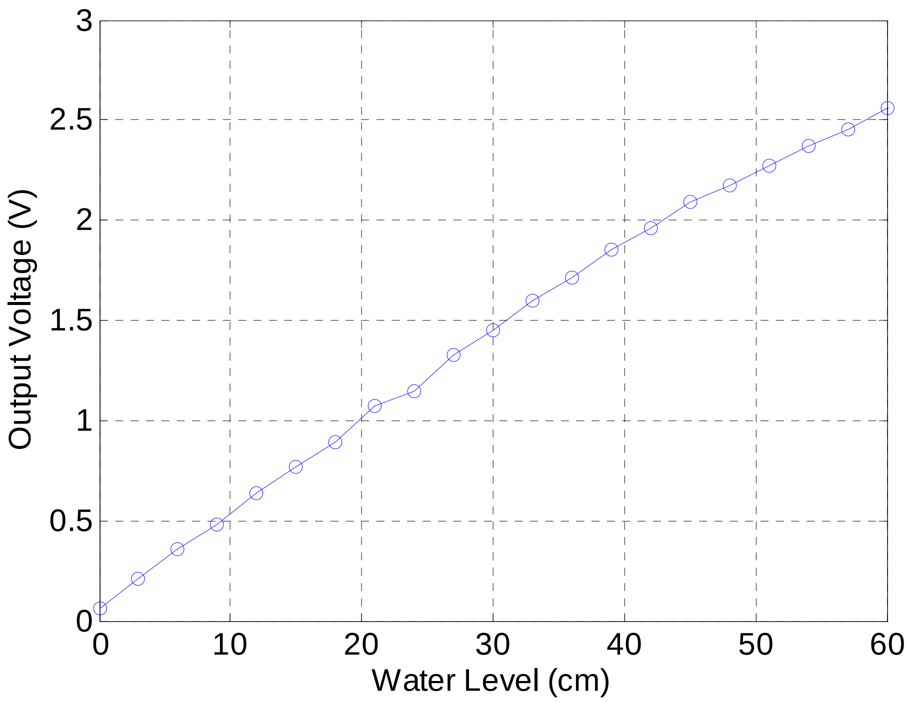

Fig. 5: The relationship between the water level and the output voltage (peak voltage)

The proposed rainfall telemetry system consists of a coaxial capacitance sensor, a high-pass filter circuit, a microcontroller, and a SMS module. The prototype is shown in Fig. 6.

Fig. 6: The prototype of the proposed rainfall telemetry system

The proposed rainfall telemetry system has a solenoid valve for releasing water at the bottom automatically. Also it has the solar and energy storage system. The system is shown in Fig. 7.

Fig. 7: The solar cell and control unit

The experimental results show that the proposed rainfall telemetry system can send the SMS data to the phone to report the rainfall level correctly. The SMS is shown in Fig. 8.

Fig. 8: The rainfall level displayed on a phone screen

IV. CONCLUSION

From the study, it has been found that the equation analysis shows that the output voltage is linearly proportional to the water level. This relationship can be used for monitoring the water level in the proposed rain gauge telemetry system. The proposed rainfall telemetry system can measure the rainfall level correctly, and can send the SMS to the phone in the morning correctly.

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